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Quantitative analysis on hazard prediction of coal and gas outburst

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Abstract

According to interrelated theory and influence factors for coal and gas outburst, the present paper sets up an evaluation index system and also applies fuzzy synthetic access method to show the result quantificational. With an actual simple, calculation process of index value and application of fuzzy synthetic appraisal method is particularly analyzed and the results show consistent quality to the fact situation preferably. Those researches can provide some theoretic references for prevention and management of coal and gas outburst.

Keywords: coal and gas outburst; evaluation index system; fuzzy synthetic appraisal method; index value

1. Introduction

In term of correlative theories, this paper analyses the mechanism of coal and gas outburst that it is integrative action by crust stress, gas pressure and physical property of coal seam. The criticality of outburst is interrelated right with those factor characteristics. Therefore, according to risk indexes and critical values, the risk degree on working faces of coal mine can be forecasted. It is not only most portion for guaranteeing safety production of coal mine, but also precondition condition for preventing and evaluating dangerous degree of gas and coal outburst.

For a long time, considerable work on forecasting coal and gas outburst have been done by engineering technology and research staff, thus various hypotheses and empirical formulas were introduced. According to coal seam characteristics, this paper sets up model and appraised outburst danger level of 7# coal seam 86 mining area in haizi mine [1], so it will provide references on gas prevention and control at the scene.

2. General situation of mine

The 86 mining area lies on westward boundary of haizi mine, and its main mining coal seams are respectively 7#, 8# and 9# which take on outburst dangerousness according to information in the past. In the region, 10# coal seam has disappeared that is non-outburst, so 86 mining area belongs to unprotected layer status. The whole district is divided into five sections, and the first mining layer is 7# coal seam that is located round lower parking-lot. According to the criterion of the prevention and control of coal and gas outburst provisions, the destruction type of coal sample on this area was analyzed, the results showed that the granularity average size index less than 0.5mm was 14.83%, the destruction type served as Ⅳ～Ⅴtype; gas pressure was 0.72 MPa; gas content was 10.08 m^3/t, gas diffusion velocity 32.955, coal seam solid coefficient 0.216.

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3. Fuzzy comprehensive evaluation of coal and gas outburst hazard

3.1. Construction of evaluation index system

On the basis of relevant theories of coal and gas outburst, the prevention and control of coal and gas outburst provisions and coal bed characteristics of haizi mine [2-5], evaluation index system of coal and gas outburst hazard was structured, and outburst critical values were determined in accordance with mine actual conditions, therefore, reference basis of theory can be obtained for evaluating outburst hazard.

Index system is consisted of two levels. The first level is in relation of physical characteristics and occurrence conditions of coal seam, as well as related cases during mining. The second level is concrete description for previous level. The index system and critical values is listed as Table 1.

Table 1. Evaluation index system and consulting critical values of coal and gas outburst hazard

first level index	Second level index	*selected items*				
U	u_{ij}	very serious	severity	general	possibility	impossible
physical characteristic U_1	Coal destroy type u_{11}	Ⅴ type	Ⅳ type	Ⅲ type	Ⅱ type	Ⅰ type
	Gas diffusion velocity u_{12}	>20	15–20	10–15	5–10	<5
	Coal Solid coefficient u_{13}	<0.3	0.3–0.5	0.5–1	1–2	>2
	gas pressure u_{14}	>1.5	1–1.5	0.74–1	0.5–0.74	<0.5
	gas content u_{15}	>20	15–20	10–15	5–10	<5
occurrence condition U_2	most shallow burial depth u_{21}	>500	300–500	200–300	100–200	<100
	Thickness variation coefficient u_{22}	>0.5	0.4–0.5	0.3–0.4	0.2–0.3	<0.2
	Permeability of Surrounding Rock condition u_{23}	very poor	Poor	General	Fairly good	Very good
	geologic structure u_{24}	Containing mass high - pressure gas	Fault and fold development	Fault and fold general	geologic structure simple	geologic structure extremely simple
Mining characteristic U_3	Initial outburst recorder u_{31}	The first 5 years	5-10 years	10-20 years	Exiting dynamic phenomena	No dynamic phenomena
	Historical number of outburst u_{32}	>10	3-10	1-3	Nothing	Nothing
	Most outburst degree u_{33}	>1000	100–1000	<100	Nothing	Nothing
	Average depth of prediction region u_{34}	More than 100metres under initial outburst altitude	50-100 metres under initial outburst altitude	Less than 50 metres under initial outburst altitude	Less than 50 metres over initial outburst altitude	More than 100 metres over initial outburst altitude
	operation mode of Prediction region u_{35}	Blasting operation	Drilling operation	Mechanical operation	General operation	laying-off

3.2. Establishing of weight sets

According to different influence grade on result, evaluation indexes all levels are scored, so those weight values can be obtained as follows:

The first level index weight values:

$$A = (0.5, 0.3, 0.2)$$

The second level index weight values:

$$A_1 = (0.1, 0.2, 0.2, 0.3, 0.2),\ A_2 = (0.2, 0.2, 0.3, 0.3),\ A_3 = (0.1, 0.2, 0.2, 0.3, 0.2)$$

3.3. Establishing of alternative sets

Each result of appraisable index is bound to correspond with corresponding quantitative value of alternative sets. The relation is showed as below Table 2.

Table 2. Comparison table of hazard result

Coal and gas outburst hazard	Very serious	Serious	General	Possibility	Nothing
Interval value	(90,100]	(80,90]	(60,80]	(40,60]	(0,40)
Quantitative value (V)	95	85	65	50	0

3.4. First-level fuzzy synthetic evaluation

The first-level fuzzy synthetic evaluation is to calculate each factor of subset so as to obtain evaluation result. In term of subjection relationship between index with result, considering actual conditions of mine, the membership degree of each factor is classified and normalized transact for first-level fuzzy synthetic evaluation system.

Taking physical characteristic of coal seam as an example, evaluation matrix R_1 is deduced by computing subjection degree of each factor. Considering index weight values A_1, evaluation set B_1 is obtained as follows:

$$B_1 = A_1 \bullet R_1 = \begin{pmatrix} 0.1 & 0.2 & 0.2 & 0.3 & 0.2 \end{pmatrix} \begin{bmatrix} 0.5 & 0.5 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0.45 & 0.05 & 0.2 & 0.3 & 0 \end{pmatrix}$$

Similarly, the evaluation set B_2 on occurrence condition and B_3 on mining characteristic of coal seam are as below:

$$B_2 = A_2 \bullet R_2 = \begin{pmatrix} 0.2 & 0.2 & 0.3 & 0.3 \end{pmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0.6 & 0 & 0.2 & 0 & 0.2 \end{pmatrix}$$

$$B_3 = A_3 \bullet R_3 = \begin{pmatrix} 0.1 & 0.2 & 0.2 & 0.3 & 0.2 \end{pmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0.2 & 0.5 & 0.3 & 0 & 0 \end{pmatrix}$$

3.5. Multilevel fuzzy synthetic evaluation

Basing on the foundation of first-level fuzzy synthetic evaluation, appraisable matrix R of whole system is constituted by all kinds subsets. Considering index weight values A, evaluation set B of outburst hazard is obtained as follows:

$$B = A \bullet R = \begin{pmatrix} 0.5 & 0.3 & 0.2 \end{pmatrix} \begin{bmatrix} 0.45 & 0.05 & 0.2 & 0.3 & 0 \\ 0.6 & 0 & 0.2 & 0 & 0.2 \\ 0.2 & 0.5 & 0.3 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0.445 & 0.125 & 0.22 & 0.15 & 0.06 \end{pmatrix}$$

3.6. Quantitative expression of evaluation results

After getting all evaluation sets, quantitative results can be deduced in accordance with corresponding relationships of alternative sets. Taking physical characteristic of coal seam as example that expressed evaluation set and quantitative value as B1 which was put forward by specialist respectively, the quantitative result is as below:

$$V_1 = VB_1' = \begin{pmatrix} 95 & 85 & 65 & 50 & 0 \end{pmatrix} \begin{pmatrix} 0.45 \\ 0.05 \\ 0.2 \\ 0.3 \\ 0 \end{pmatrix} = 75$$

Similarly, the quantitative result V_2 on occurrence condition, V_3 on mining characteristic and V on whole hazard of coal seam are as below:

$$V_2 = VB_2' = \begin{pmatrix} 95 & 85 & 65 & 50 & 0 \end{pmatrix} \begin{pmatrix} 0.6 \\ 0 \\ 0.2 \\ 0 \\ 0.2 \end{pmatrix} = 70 \qquad V_3 = VB_3' = \begin{pmatrix} 95 & 85 & 65 & 50 & 0 \end{pmatrix} \begin{pmatrix} 0.2 \\ 0.5 \\ 0.3 \\ 0 \\ 0 \end{pmatrix} = 81 \qquad V_4 = VB_4' = \begin{pmatrix} 95 & 85 & 65 & 50 & 0 \end{pmatrix} \begin{pmatrix} 0.445 \\ 0.125 \\ 0.22 \\ 0.15 \\ 0.06 \end{pmatrix} = 74.7$$

4. Analysis of outburst hazard prediction

Generalizing appraisable results, we know that the whole outburst hazard quantitative value is 74.7 that corresponds to general of alternative sets, so it means that there is a potential outburst during coal mining, and it is necessary to prepare for prevention outburst work from equipment, personnel and management. The score on physical characteristic and occurrence condition of coal seam is respectively 75 and 70 that correspond to general of alternative set all, therefore it means that 7# coal seam take on the characteristic of outburst hazard itself, and we must highly pay attention to those geologic structure as fault and fold. The score of mining characteristic is 80 that belongs to severity grade of alternative set, so it means that man-made mining factors are mainly action to place a premium on outburst such as laneway lay, mining sequence, mining mode and ceiling timbering etc.

During laneway was carved out of 7# coal seam, gas exceptional effusion and some dynamical phenomenon take place ever frequently, so it shows that locale coal seam outburst hazard is coincident with theory prediction result. The research production on index system and appraisable method are provided with practicality appliance value.

5. Conclusion

(1) With the extension of mining level, coal and gas outburst hazard must be increased, so it is a straight matter to evaluate fatalness size for field worker. This paper analyzed influence factors of coal and gas outburst from physical characteristic, occurrence condition and mining characteristic, and improve more evaluation index system, therefore it will provide some theoretic reference for prevention and management of coal and gas outburst.

(2) In allusion to faintness characteristic of some evaluation indexes, fuzzy synthetic appraisal method is adopted and results are expressed quantifying, so practicability and maneuverability are distinct more.

(3) The outburst hazard of 7# coal seam 86 mining area in haizi mine was evaluated, and the results are significant for field workers to prevent gas problem emphatically and purposely.

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